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NAVAL POSTGRADUATE SCHOOL

Monterey, California

THE USE OF A LINEAR RATING SCALE IN SELECTING A SUBCRITICAL TRACKING TASK PARAMETER

by

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NAVAL POSTGRADUATE SCHOOL

Monterey, California

ABSTRACT:

The results of a brief experimental study are presented in which subjective operator opinion, expressed on a linear, nonadjectival rating scale, was utilized in selecting a subcritical tracking task parameter.

FOREWARD

This report describes the results of a brief experiment in which a simplified rating scale was utilized in selecting a subcritical tracking task parameter. The work was performed by Dr. Hess at the Air Force Flight Dynamics Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio.

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I. INTRODUCTION

References 1 and 2 describe two simple experiments involving linear, nonadjectival, nonordinal rating scales, an example of which is shown in Figure 1. Schufeldt[1] first introduced this scale as a specialized form of McDonnell's Global rating concept[3]. Hess applied the linear scale to a compensatory tracking task with some success.

The purpose of this brief study was to determine the utility of Schufeldt's scale in selecting a tracking system parameter via operator opinion. To be more specific, in the single axis compensatory task of Figure 2, an "optimum" control stick sensitivity was to be chosen via operator opinion expressed on a linear, nonadjectival, nonordinal scale similar to that of Figure 1.

II. EXPERIMENT

A. The Subcritical Task

The system of Figure 2 was mechanized on an analog computer. The pertinent system parameters are listed in Table I. As in Reference 2, the manipulator was the Measurement Systems Incorporated small isometric control stick. The system input consisted of the sum of five sine waves. The system error was displayed to the operator as the displacement of a horizontal line on an oscilloscope screen (Figure 3).

The controlled element was the "subcritical" system utilized by Jex and Allen[4] in previous human response tests. The rationale behind the choice of the subcritical task is given in Reference 2.

B. Experimental Procedure

The control stick sensitivity or gain was varied from

$$0.1 < K_c < 5.0 \quad \text{cm/newton}$$

Five values of K_c were chosen in this range and utilized in the experiment. These gains are given in Table I. $K_c = 0.9$ cm/newton was selected as the nominal stick gain and was utilized in the brief training period which each subject underwent. The experimental procedure went as follows:

1. The experiment was briefly described to the operator. The rating sheet of Figure 4 was shown to him.

2. With $K_c = 0.9$ cm/newton, the operator performed a number of runs of 100 second duration. This constituted the training period. The number of complete runs without loss of control varied; no less than three but no more than five.

3. After completing the training period the operator was told that the nominal gain was to be given a rating of 5.0 on the scale of

Figure 4. The operator was told that this rating was arbitrary and did not necessarily indicate the mean "difficulty" of the systems he would control.

4. The remaining gains were presented in the following order.

K_c = 0.1, 0.3, 5.0, and 2.5 cm/newton

For each of these gains the operator made two runs of 100 second duration. After each set of two runs the operator was asked to rate the difficulty he encountered in controlling the system relative to the nominal system as per the rating scale and instructions of Figure 4. Between each set of two runs, the operator was allowed a short tracking run with the nominal gain.

5. The procedure was repeated for the next operator with the exception that the off-nominal gains were presented in opposite order, i.e.,

K_c = 2.5, 5.0, 0.3, and 0.1 cm/newton

This order reversal was continued throughout the experiment.

C. Discussion

It should be emphasized that the brevity of the experiment was deliberate. It was felt that if the rating scale were indeed useful in selecting a single tracking parameter, it should not require prolonged operator training to provide results.

In some instances, the requirement of completing five runs in the nominal case and two runs in the off-nominal cases was waived. This was necessary in those cases where the operator was simply unable to maintain control. It was felt that attempting further runs in these cases would only induce fatigue.

III. RESULTS

Figures 5 through 13 show individual operator ratings vs stick gain K_c. Figure 14 shows the mean ratings and standard deviations. Figure 15 is a strip chart recording of a typical run. While RMS performance figures were recorded during the experiment, they have not been included here. The small number of runs at each configuration did not provide a large enough data base for calculating average RMS values.

The ratings of one of the subjects was not used in Figure 14. As Figures 12 and 13 indicate, the ratings of subjects 8 and 9 failed to indicate a relative minimum. In verbal debriefing these subjects stated that the higher stick gains required much less muscular effort than the lower ones and for this reason they were rated as most acceptable. However, subject 9 was unable to complete a single run at the highest gain whereas subject 8 achieved his best performance there. Since the rating instructions stated that "difficulty" meant difficulty in keeping the line centered, it was felt that subject 9 had misunderstood or misinterpreted the instructions. For this reason the ratings of subject 9 were discarded while those of subject 8 were retained.

IV. CONCLUSIONS

While the rating data summarized in Figure 14 exhibits a fair degree of scatter, the mean ratings are amenable to a smooth curve fit. The minimum rating is roughly 5.0 at K_c = 1.5 cm/newton. There is very little degradation in acceptability for $.9 < K_c < 2.5$ cm/newton.

Briefly then, the linear, nonadjectival, nonordinal scale has demonstrated its capability to allow a tracking system parameter to be chosen via operator opinion. This was accomplished in a situation where the use of an adjectival scale would have been inappropriate.

The author feels that allowing the stick sensitivity to vary slowly from 0.1 to 5.0 cm/newton in the training runs would have been superior to anchoring a single point on the scale (5.0) by associating it with a single sensitivity (.9 cm/newton). Such *a priori* knowledge of system variability would have allowed the operator to use the scale more intelligently.

V. REFERENCES

1. Schufeldt, C., "A New Approach to Pilot Rating Scales," M.S. Thesis, August 1971, Dept. of Aeronautics, U.S. Naval Postgraduate School, Monterey, California.

2. Hess, R.A., "The Use of a Nonadjectival, Nonordinal, Linear Rating Scale in a Single Axis Compensatory Tracking Task," NPS-57He7191A, September 1, 1971, U.S. Naval Postgraduate School, Monterey, California.

3. McDonnell, J.D., "Pilot Rating Techniques for the Estimation and Evaluation of Handling Qualities," AFFDL-TR-68-76, December 1968, Air Force Flight Dynamics Lab, Wright-Patterson Air Force Base, Ohio.

4. Jex, H.R. and Allen, R.W., "Research on a New Human Dynamic Response Test Battery," Proceedings of the Sixth Annual Conference on Manual Control, April 1970, pp. 743-777.

VI. TABLE AND FIGURES

TABLE I

Subcritical Task Parameters

K_c = display/control sensitivity

= cm scope deflection/newton stick force

= 0.1; 0.3; 0.9; 2.5; 5.0; cm/newton

K_D = display viewing gain for 50 cm nominal viewing distance

= 1.0 degree visual angle/cm display deflection

$i(t)$ = input

= (.494 sin .502 t + .460 sin 1.256 t + .204 sin 3.01 t + .0543 sin 6.282 t + .0306 sin 10.46 t) cm

$\overline{i^2(t)}$ = mean square input

= .25 cm^2

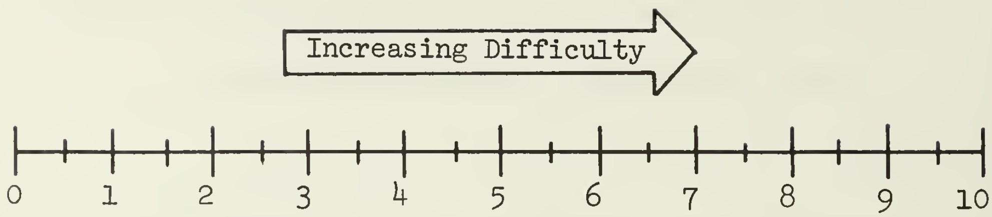

Figure 1. Schufeldt's Nonadjectival, Nonordinal, Linear Rating Scale

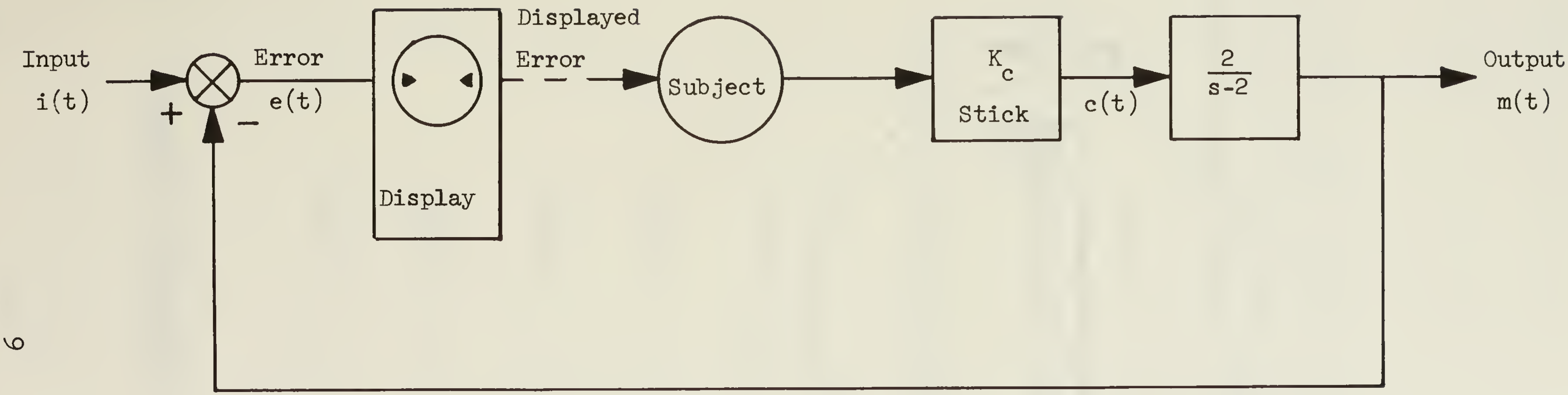

Figure 2. The Subcritical Tracking Task

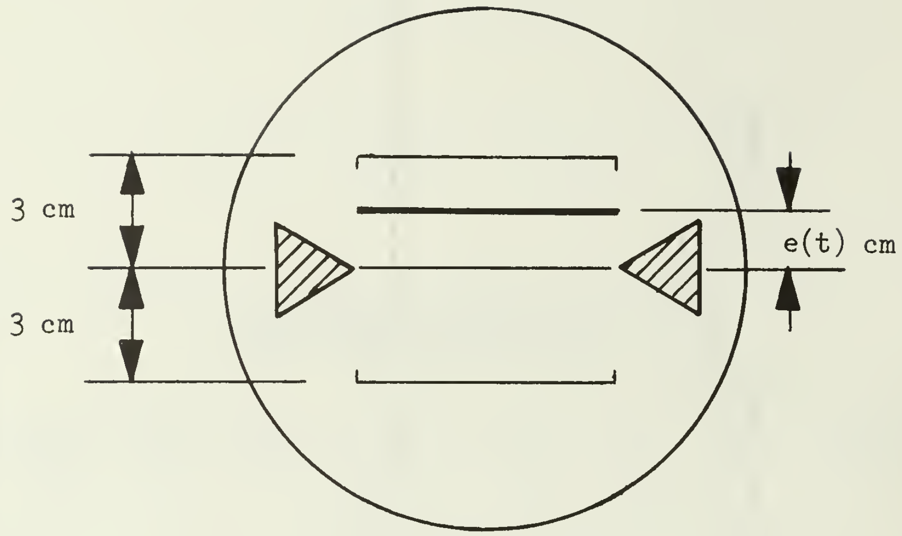

Figure 3. Oscilloscope Display

SUBJECT______________________________

DATE_________________________________

Using the scale below, indicate the degree of difficulty you encountered in controlling systems 2 through 5 relative to system 1. Here "controlling" refers to keeping the line centered.

Increasing Difficulty

System 1 5.0

System 2 ______

System 3 ______

System 4 ______

System 5 ______

Figure 4. The Rating Sheet

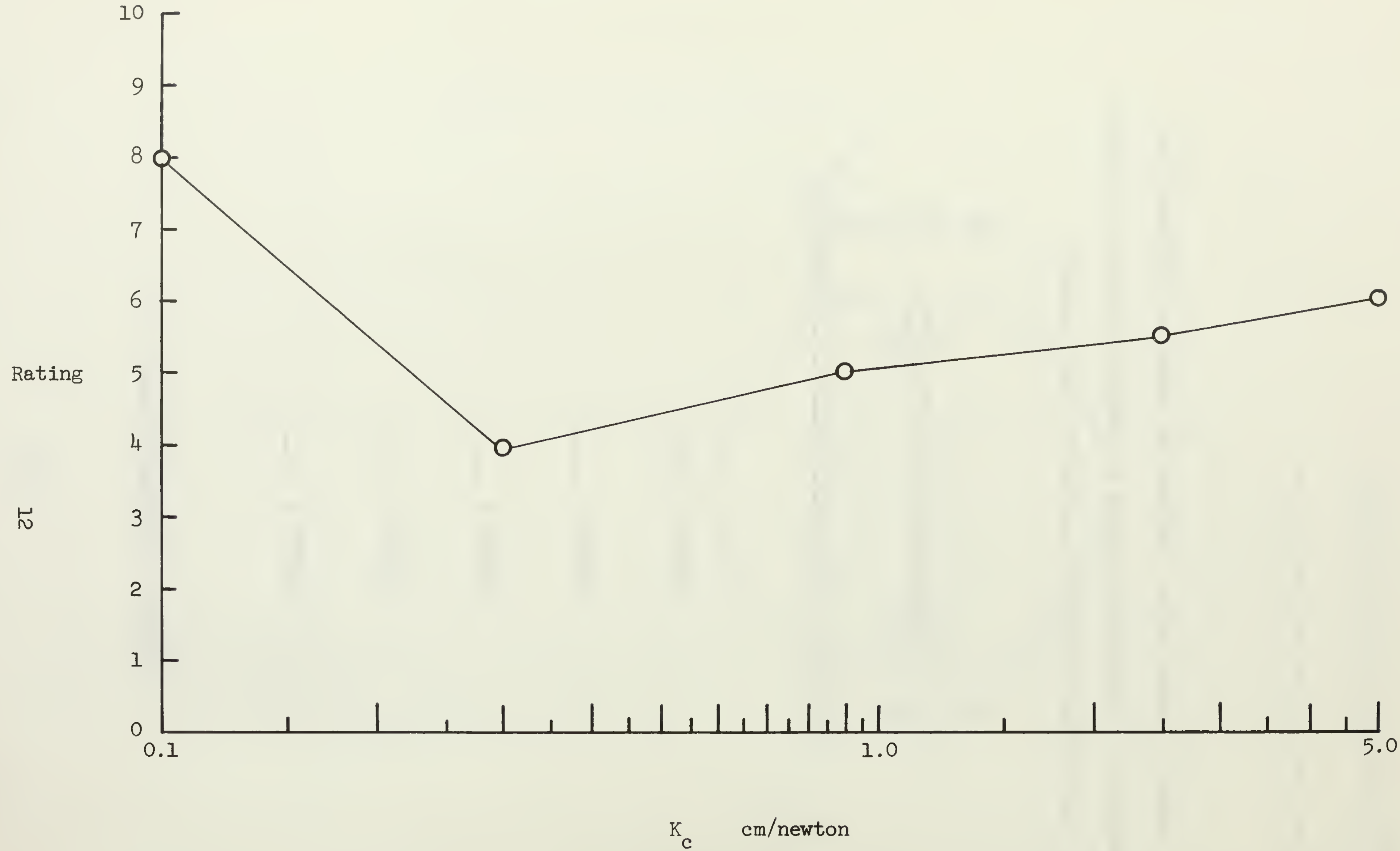

Figure 5. Ratings vs Stick Sensitivity Subject 1

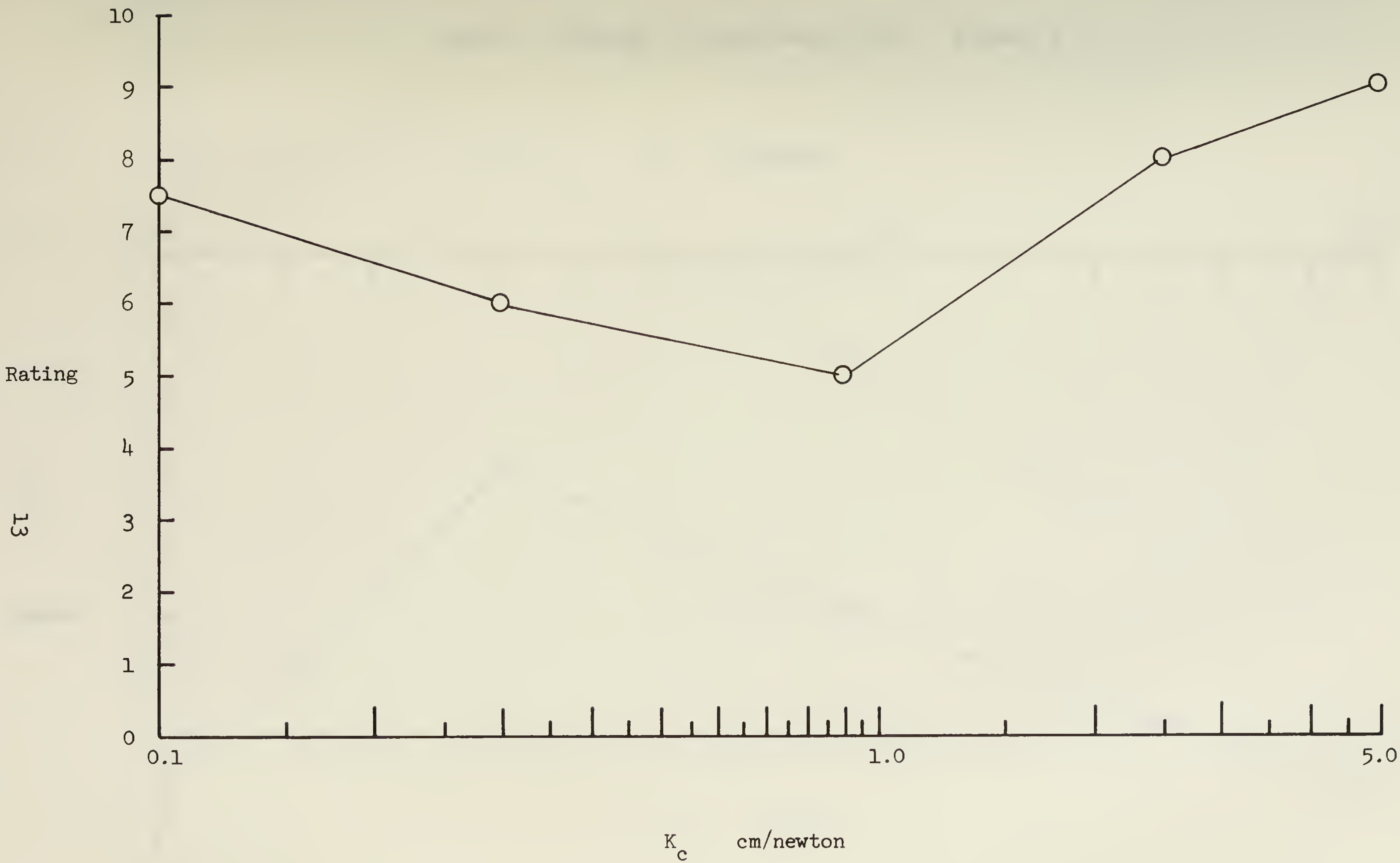

Figure 6. Ratings vs Stick Sensitivity Subject 2

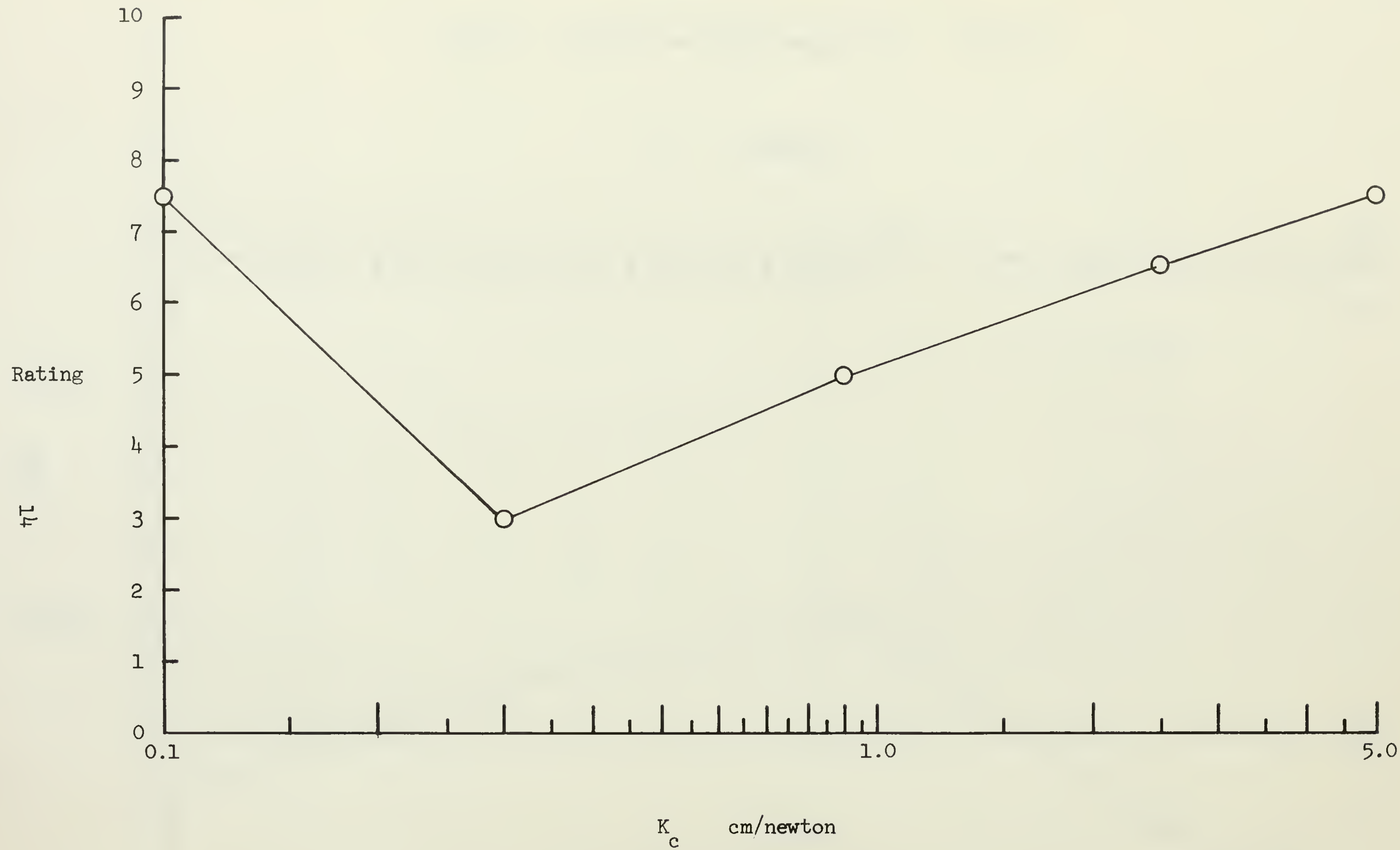

Figure 7. Ratings vs Stick Sensitivity Subject 3

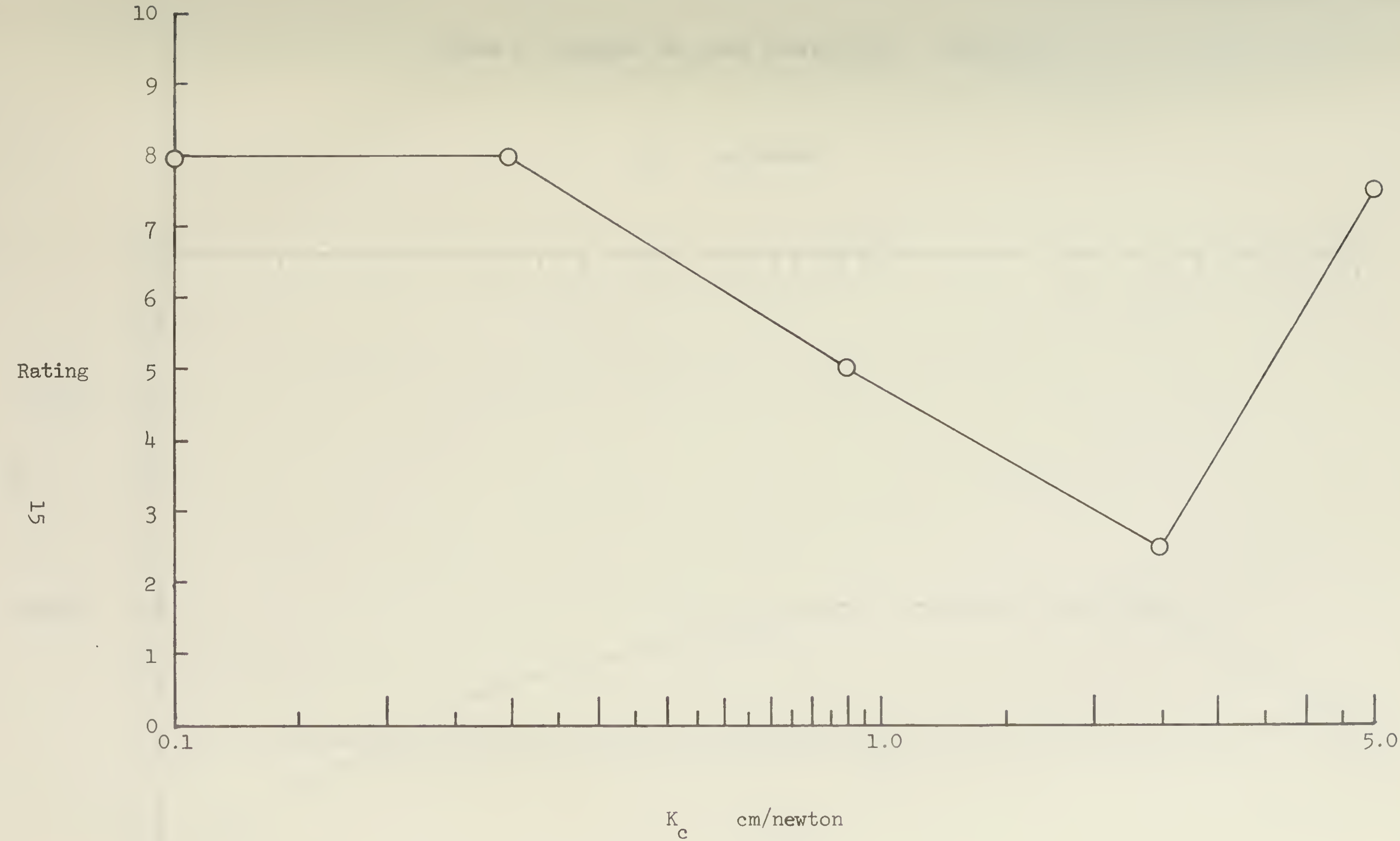

Figure 8. Ratings vs Stick Sensitivity Subject 4

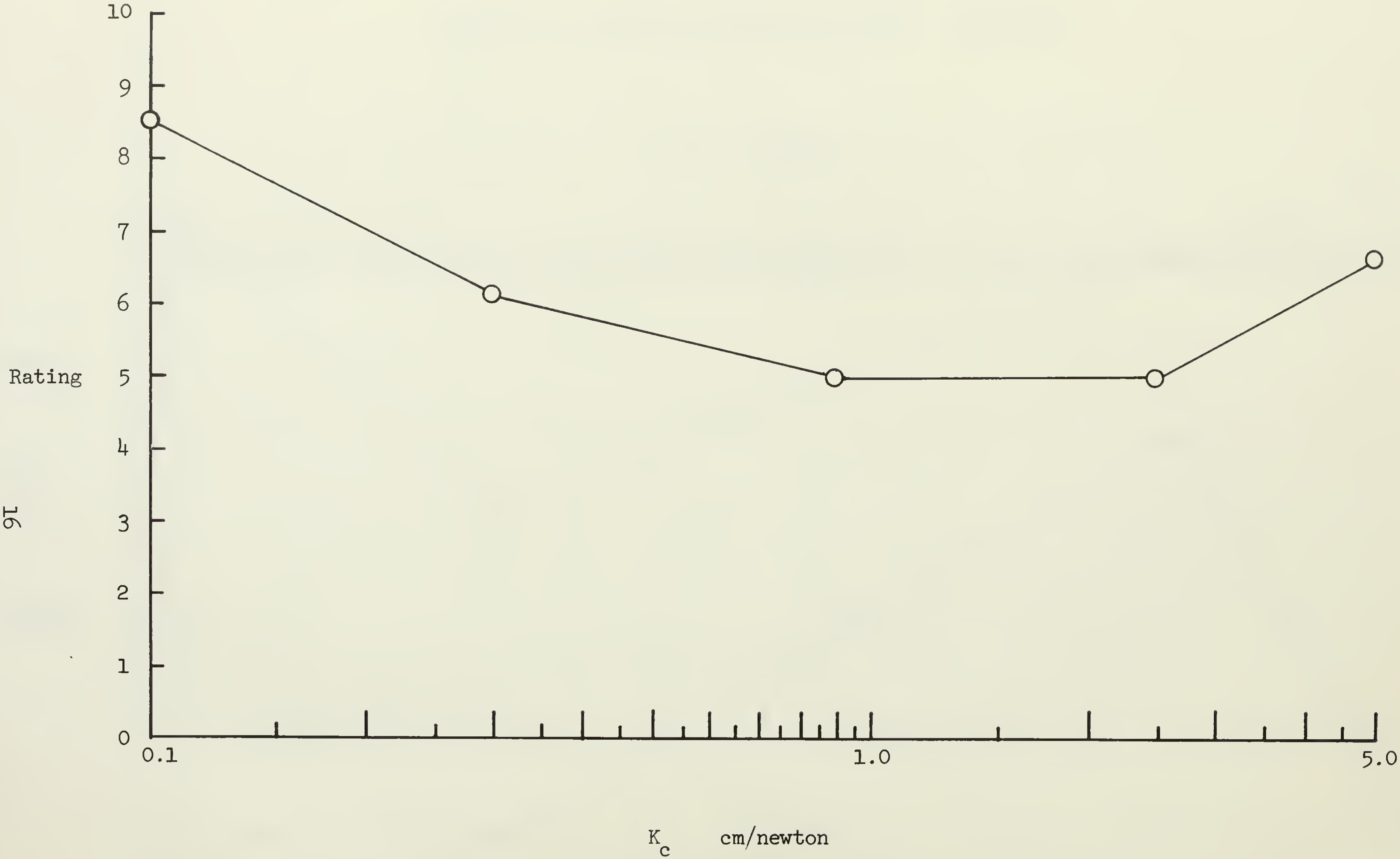

Figure 9. Ratings vs Stick Sensitivity Subject 5

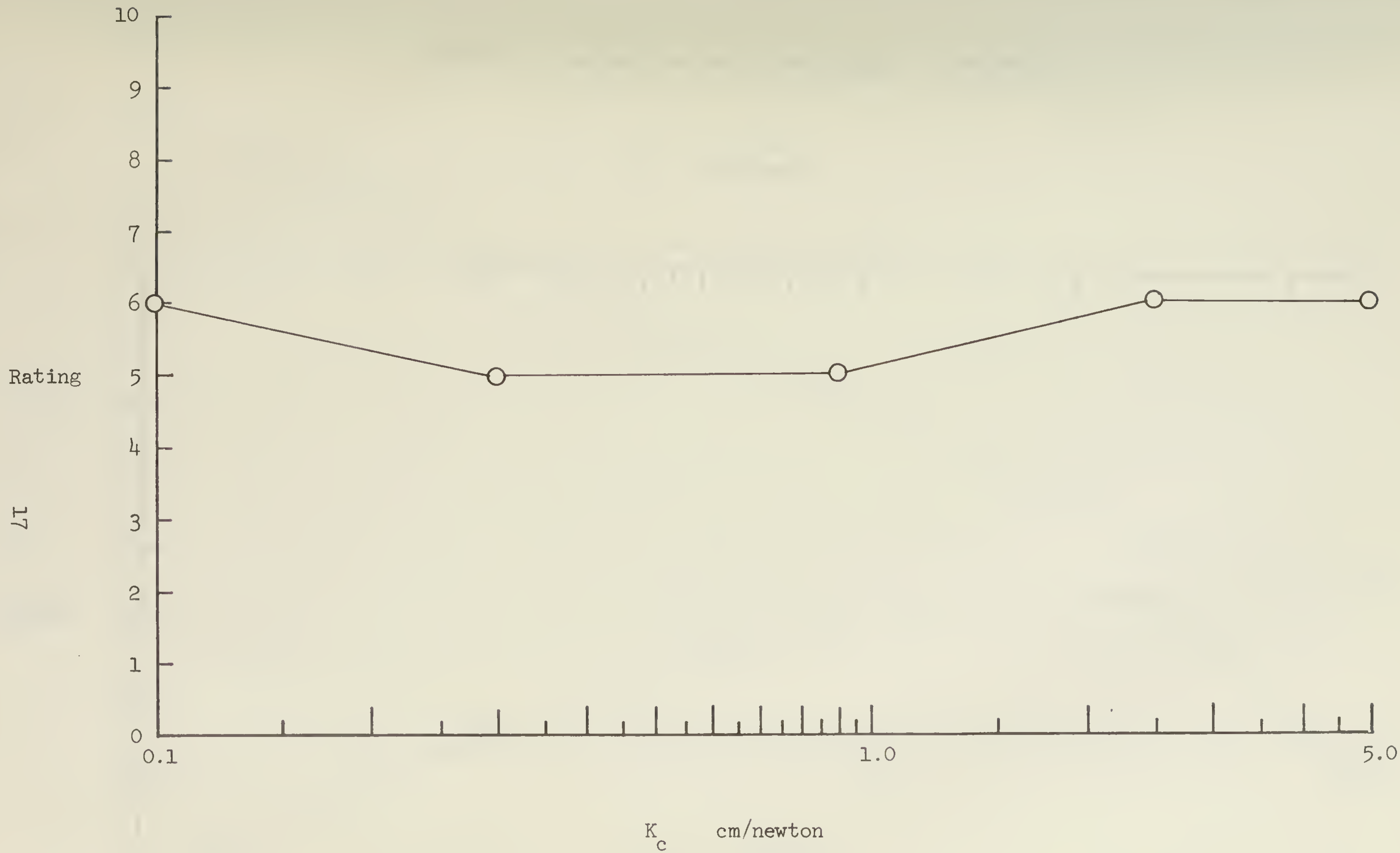

Figure 10. Ratings vs Stick Sensitivity Subject 6

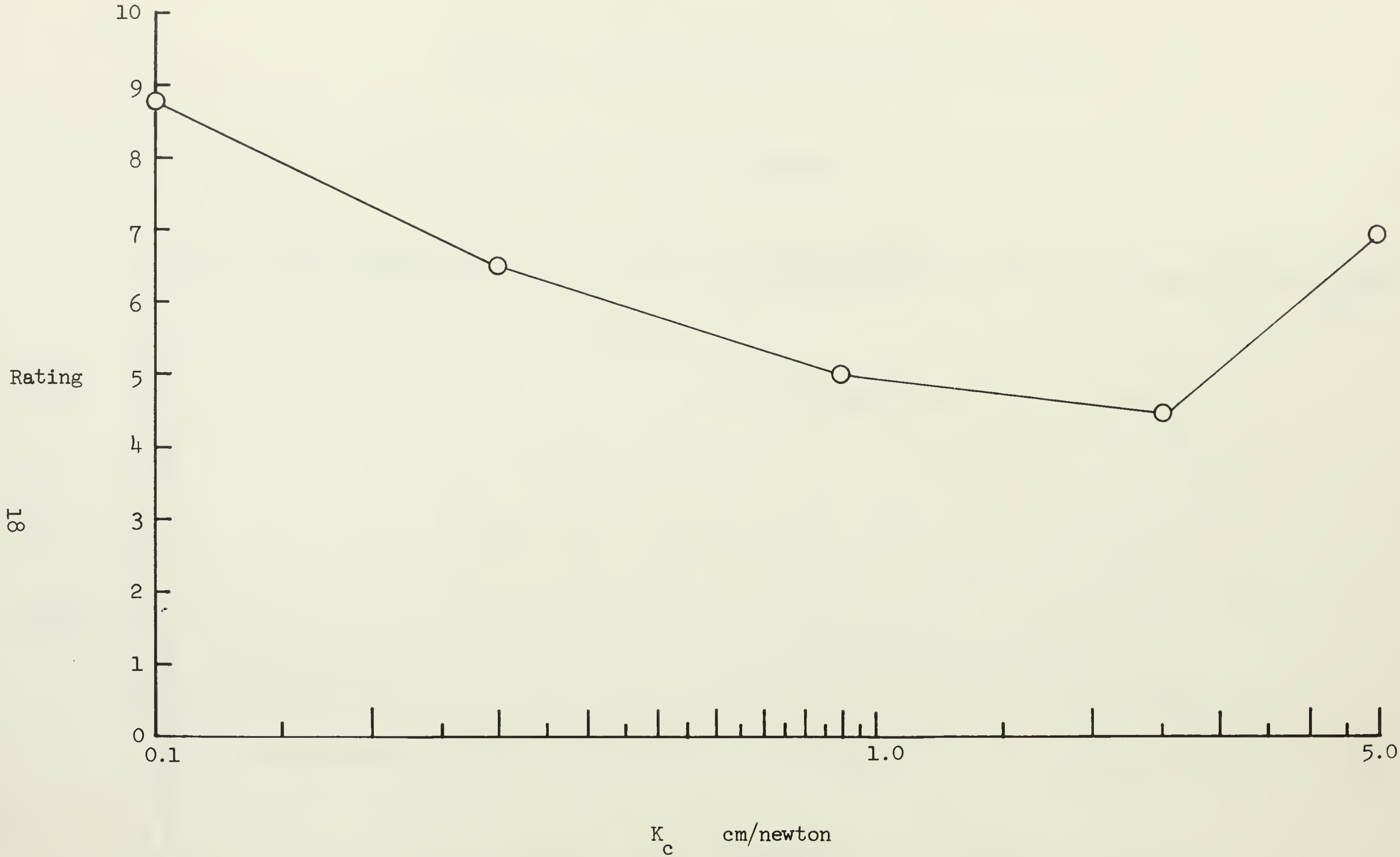

Figure 11. Ratings vs Stick Sensitivity Subject 7

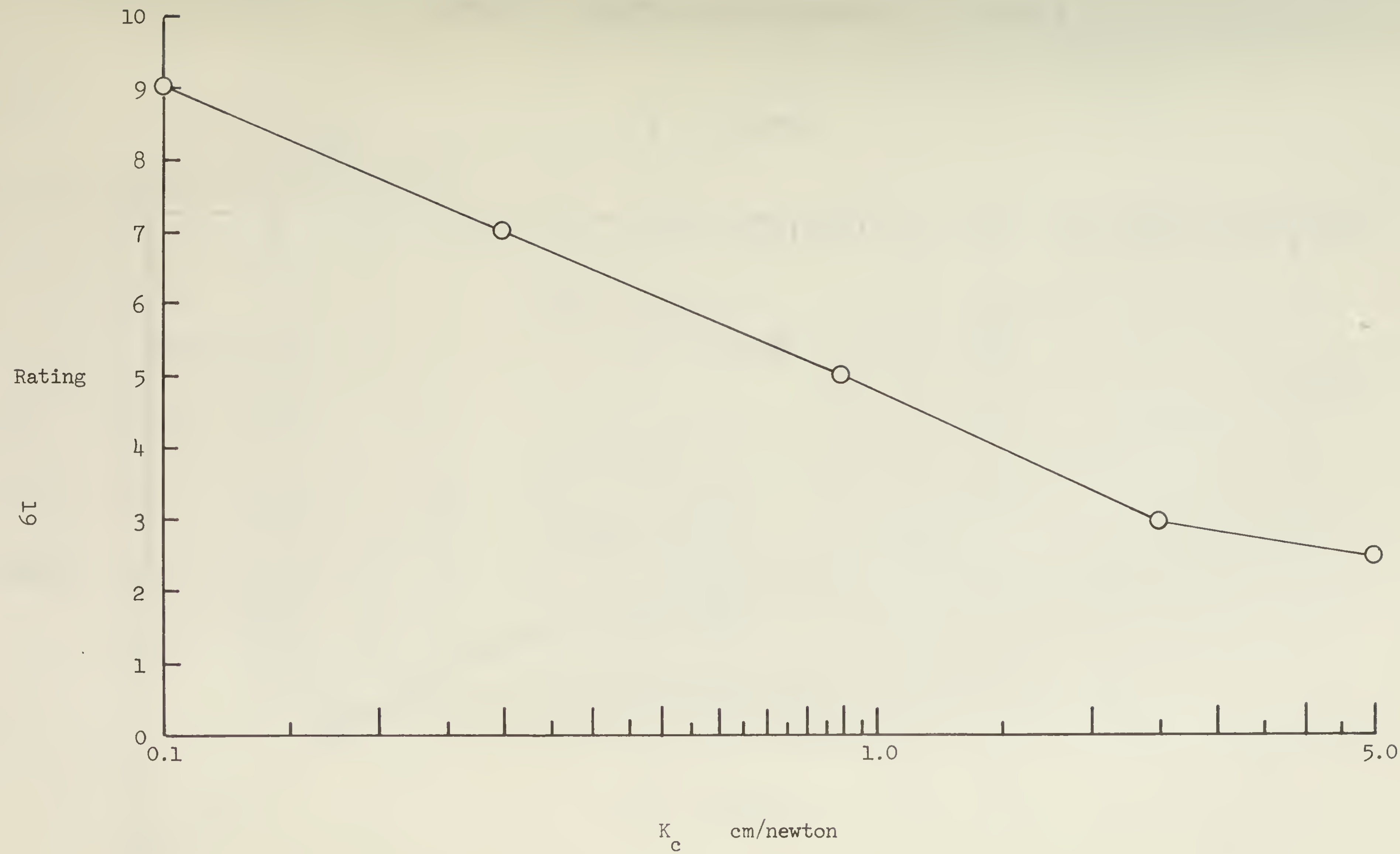

Figure 12. Ratings vs Stick Sensitivity Subject 8

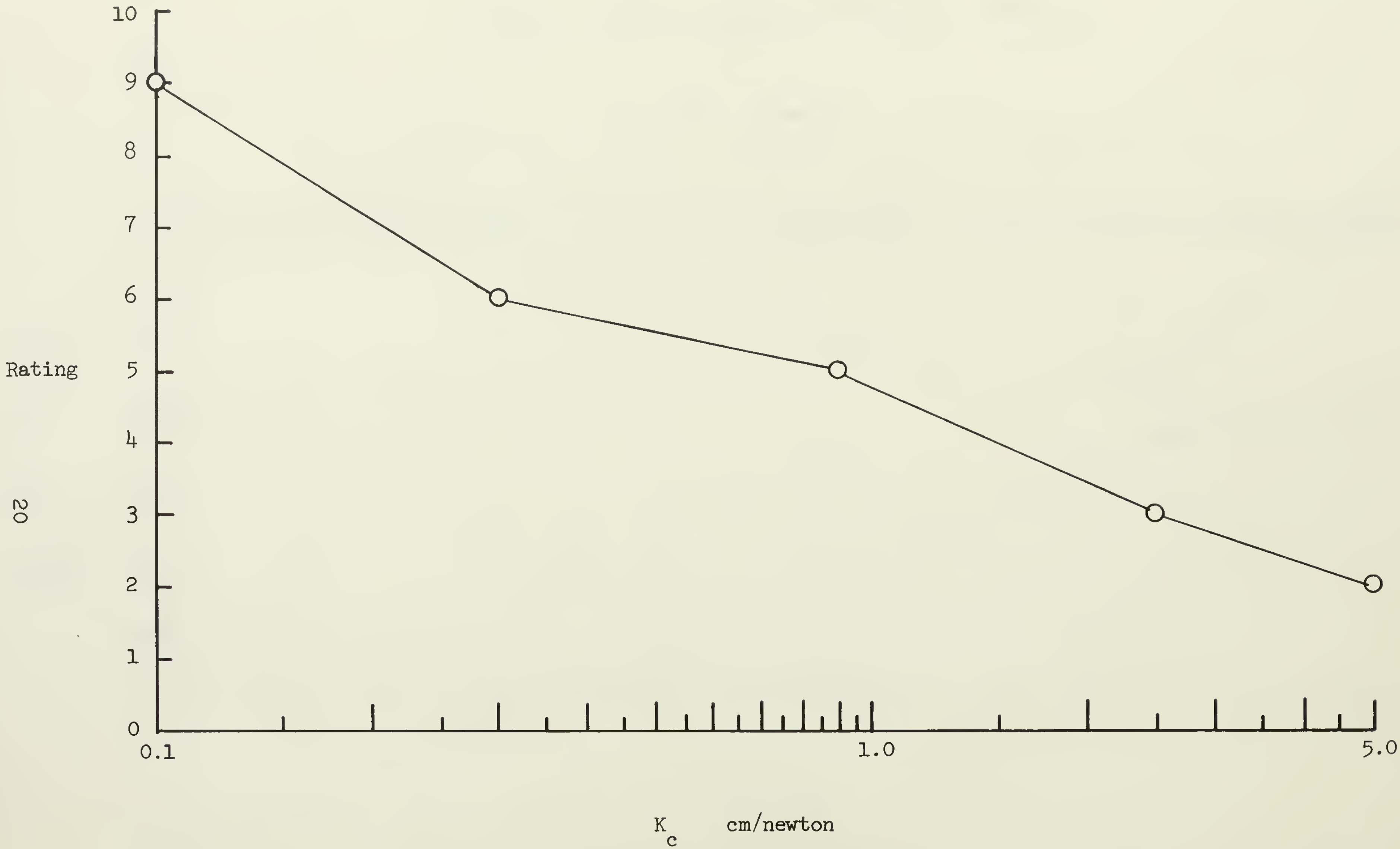

Figure 13. Ratings vs Stick Sensitivity Subject 9

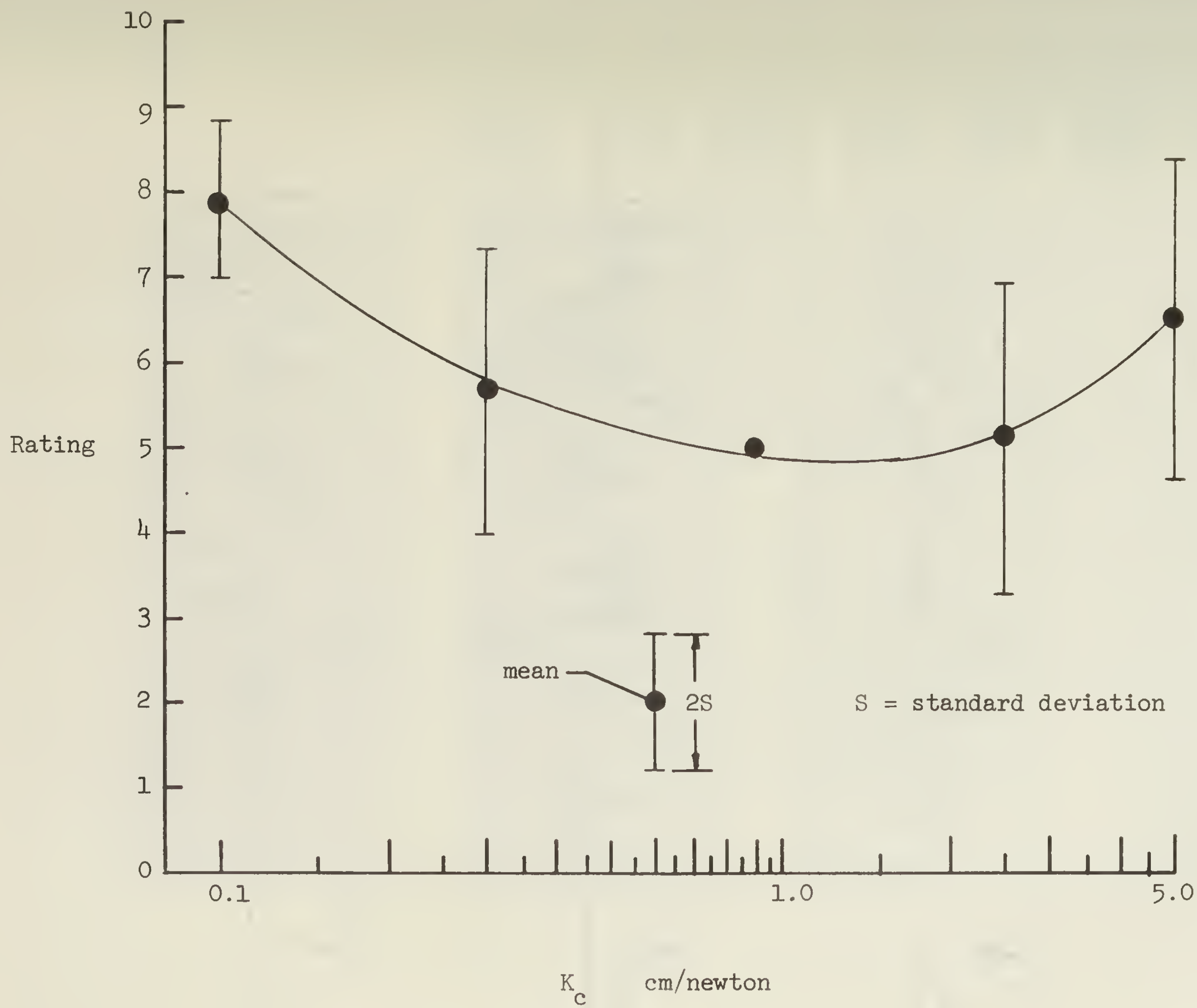

Figure 14. Mean Ratings vs Stick Sensitivity

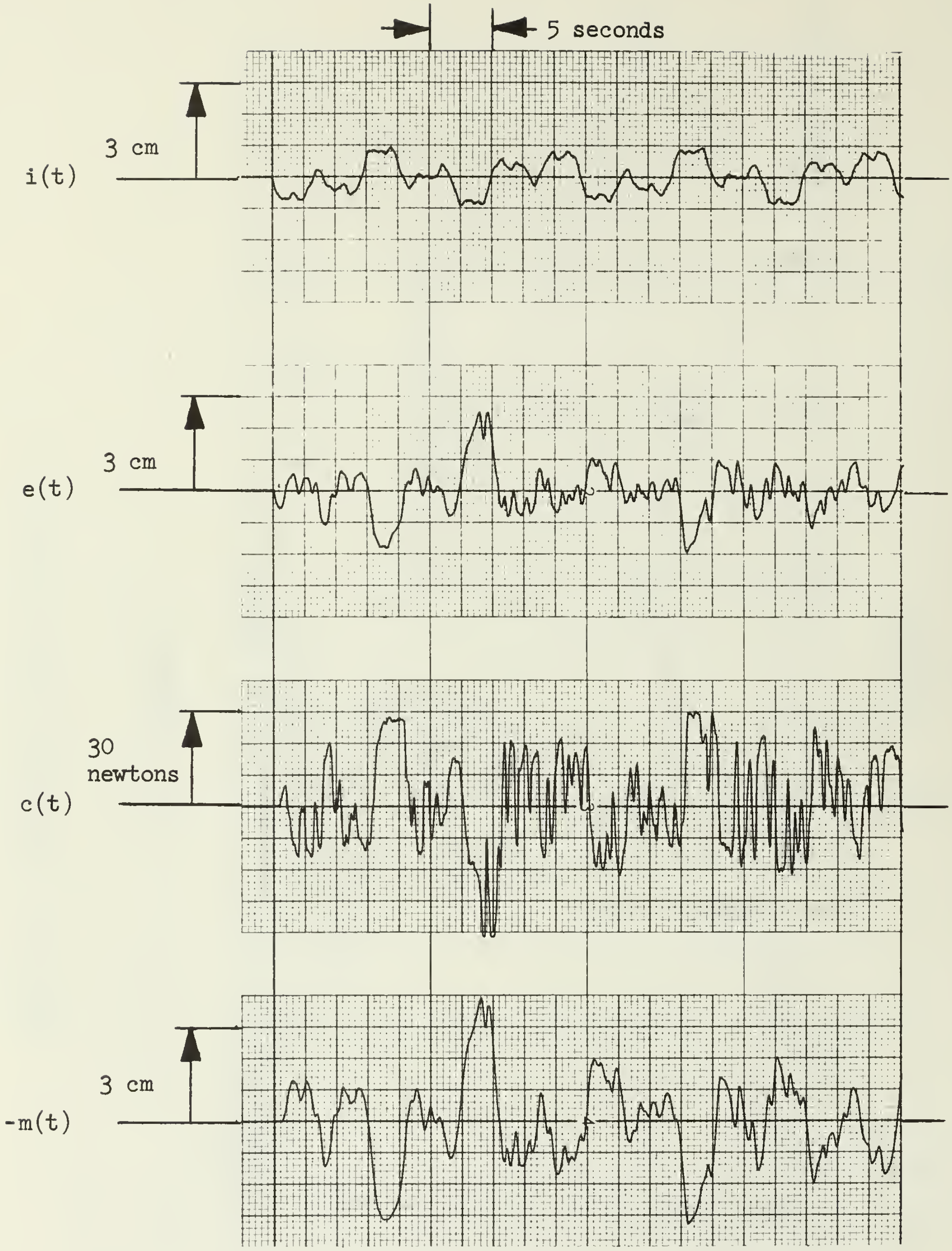

Figure 15. Typical Time Histories $K_c = 0.1$, Subject 8

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13. ABSTRACT

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14 KEY WORDS	LINK A		LINK B		LINK C	
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